An Addition to Meniscus-Monitoring Photoconductive Cell Circuits to Increase Their Reliability[1]

Photoconductive cells are extremely useful in automatic control of operations based on the level of liquid in a tube. These devices suffer from two defects. One is a dependence on the rate of meniscus movement, i.e., if the meniscus is moving very slowly the photocell fails to detect it. The second is occasional failure under normal operating conditions. The circuit described here overcomes these problems.

The failures mentioned occur because the photoconductive cells are not DC-coupled, and the output control circuit will not function unless the photocell resistance changes rapidly enough. The auxiliary circuit described eliminates these problems by the use of DC-coupling of the signal received from the photocell, and by using the voltage comparator technique.

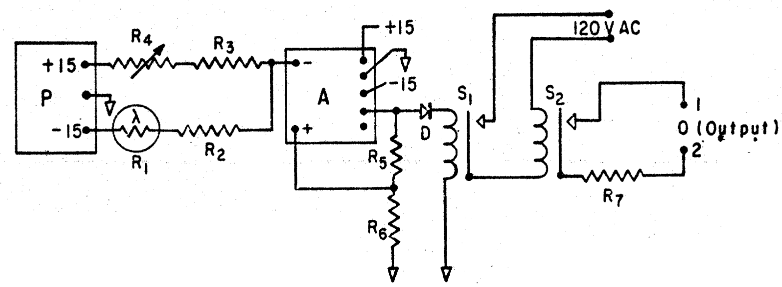
In this laboratory two systems employing photoconductive cells for meniscus detection are in use, one for dispensing liquid into a fraction collector tube when a preset volume has been collected (Buchler Instruments No. 3-4006), the other a Cannon-Fenske viscometer (Hewlett-Packard Autoviscometer No. 5901A). In the latter, two photoconductive cells are utilized, one for turning the timer on when the meniscus passes the upper level (on its way down), the other for turning it off when the meniscus passes the lower level. In addition, the upper photocell serves, when the meniscus is on its way up, to trigger the delay circuit which later releases the pressure driving the liquid upward, thus initiating outflow (drainage) when the meniscus has reached a suitable level.

Modification of the meniscus detection circuit is carried out as follows

[1] Mention of commercial names does not imply endorsement by the U. S. Department of Agriculture.

(Fig. 1). O represents the (output) control circuit (exclusive of the photocell), e.g., the circuit actuating the dispensing motor of the volumetric fraction collector or the timer of the viscometric system. Before introduction of the auxiliary device, the photocell (R_1) was connected to O at points 1 and 2. R_7 simulates, and is made approximately equal to, the resistance of the photocell when it is observing a tube full of (transparent) liquid; this is the lowest resistance of the detector during operation. It is best calculated from measurements, with the original circuit consisting of O and R_1, of the voltage across and the current through the photocell under operating conditions, with a liquid-filled tube. For one of our circuits $R_7 = 1000$ ohms.

The setting of the potentiometer R_4 varies with the type of photocell and the optical characteristics of the tube and liquid being observed. It is adjusted as follows. With the tube full and the auxiliary circuit in operation, vary R_4 manually until the point is found where S_2 clicks closed and open when R_4 is varied back and forth only slightly. Disconnect the circuit from line and measure R_4. Reconnect the circuit, empty the tube, and again find the triggering point. After disconnecting the source of power, again measure the resistance of the potentiometer, R_4. Now adjust the potentiometer so that its resistance is approximately midway between the two values found.



R_1 = Photoconductive Cell
R_2 = 10K Ohms
R_3 = 10K Ohms
R_4 = 50K Ohms Potentiometer
R_5 = 150K Ohms
R_6 = 100 Ohms
R_7 = See Text

∇ = Common of power supply
P = DC Power supply Phipps model 301
D = Diode 1N457A
S_1 = Relay, Phipps OF-1A-12
S_2 = Relay, Potter & Brumfeld KRP 11AG DPDT 10A 120VAC
A = Operational Amplifier Zeltex ZEL-1C

FIG. 1. Block diagram of auxiliary device for photocell monitoring circuits.

The circuit is now in adjustment to discriminate between air and the liquid used. The intensity of light seen by the photocell is at a maximum, and its resistance at a minimum, when liquid is in the light path. The intensity is minimal, and the resistance maximal, when the meniscus is in the path. With air in the tube the values are intermediate. Consequently, when R_4 is adjusted as described, the circuit will be triggered (i.e., S_2 will change state) when the region observed by the detector changes from meniscus to liquid (or vice versa). It will not be triggered on a change from air to meniscus (or vice versa). This property prevents double triggering, which would preclude use of the device with some circuits, such as the Hewlett-Packard viscometer.

The device is fundamentally a voltage comparator. Instead of comparing voltages, resistances are compared by keeping the voltage inputs constant and opposite in polarity. A critical variation in R_1 (Fig. 1) will produce a change of polarity in the operational amplifier (1), thus tripping the relays and actuating O. R_5 and R_6 act to produce hysteresis between the positive and negative states of the output of the operational amplifier.

Since the state of the relays is independent of the rate of change of R_1, a change of state (closure) is ensured when the meniscus passes the photocell, regardless of its rate of movement. The rise time of the output signal resulting on closure of S_2 is very fast ($\ll 1$ msec), ensuring proper operation of the output circuit.

With a viscometer two circuits of the type described are required, one for each photocell. These may share a common power supply, and are conveniently packaged in one housing.

The circuit would appear well suited for monitoring opaque solutions. In this case the direction of the diode should be opposite to that shown in Fig. 1, and it may be necessary to replace the potentiometer R_4 with one of higher resistance. For other applications it may be desirable to adjust R_4 to discriminate the meniscus from air; in this case too it may be necessary to use a potentiometer of larger resistance.

The reliability of the circuit described is very high; in approximately 1800 operations (activation of output circuit) we have observed no case of failure. Prior to its use numerous costly failures were suffered.

REFERENCE

1. Philbrick/Nexus Research, "Applications Manual for Operational Amplifiers," p. 58, Sect. II.41, and p. 101, Sect. III.79 (1968).

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